



ME THESIS

Long-term Performance of Timber-Concrete Composite Flooring Systems

A thesis submitted in partial fulfilment
of the requirements for
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CERTIFICATE OF ORIGINAL AUTHORSHIP

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

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September 2015

TO MY WIFE NEBYAT
&
MY DAUGHTER MIKAL

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LIST OF NOTATIONS

Δ	Deflection (mid-span deflection)
ρ	density
Δ	elastic deflection of the system
δ	deflection
b	floor width
B_c	width of concrete topping
CO_2	carbon dioxide
d	diameter of the shear connector
D_C	theoretical full composite deflection
D_I	measured partial composite deflection
D_N	theoretical fully non-composite deflection
D_w	depth of LVL web
E	modulus of elasticity; efficiency of composite
E_{cj}	mean MOE of concrete at the appropriate age
EI	flexural stiffness
$(EI)_{eff}$	effective bending stiffness
E_x	mean modulus of elasticity of LVL in x-direction
F, P	point load
f'_b	characteristic bending strength
f'_c	characteristic compression strength parallel to grain
f'_p	characteristic compression strength perpendicular to grain
f'_s	characteristic shear strength
f'_{sj}	characteristic shear strength at joint details
f'_t	characteristic tensile strength
f_b	mean bending strength
f_c	mean compression strength
f_{cm}	mean value of the compressive strength of concrete at the relevant age
f_t	mean tensile strength
f_v	mean shear strength

g	acceleration due to gravity (9.81 m/s ²)
G	shear modulus
I	moment of inertia
k	stiffness
$K_1, K_4, k_6, K_7, K_9, K_{11}, K_{12}$	Modification factors for timber as per AS/NZS 1720
k_{17}	factor for multiple nailed joints
K_{serv}	serviceability limit state stiffness
K_u	ultimate limit state stiffness
L, l	span
L_b	shear-free span between load points
m	mass of the floor ; mass per unit length; mass per unit area
M_i	initial mass of moisture content test piece
M_o	dry weight of moisture content test piece
N^*t	Axial force on timber
M^*	Design bending moment
M^*t	Design bending moment on timber
φN_R	Resisting tensile strength
φM_R	Resisting bending moment
Q_k	strength of shear connectors
s_e	spacing of the shear connectors at the ends of the beam
s_{eff}	effective constant spacing of the shear connectors
s_m	spacing of the shear connectors in the middle of the beam
s_{min}, s_{max}	Minimum and maximum spacing of the connectors
T_c	thickness of concrete topping
T_f	thickness of LVL flange
T_w	thickness of LVL web
W	effective weight of the floor
V^*	Design shear force
w	maximum short-term deflection; uniformly distributed load per unit length (Chapter 7)
$\mathcal{G} \cdot c$	Partial safety factor for concrete

$\gamma \cdot m$	Partial safety factor for timber
$\gamma \cdot con$	Partial safety factor for connection
γ	reduction factor (gamma)

LIST OF ACRONYMS

BM	bird-mouth
CA	composite action
CoV	coefficient of variation
MOE	modulus of elasticity
FE	finite element
FEA	finite element analysis
FEM	finite element model
Glulam	glue laminated timber
LVDT	linear variable differential transformer
LVL	laminated veneer lumber
LWC	Light weight concrete
MC	moisture content
NS	normal screw
NZ	New Zealand
B-NS	Beam with normal screw connector
B-4N	Beam with four notch and with coach screw connector
B-6N	Beam with six notch and with coach screw connector
B-SFS	Beam with SFS screw as connector
Pty Ltd	proprietary limited
PSL	Parallel stranded lumber
RH	Relative air humidity
SCC	steel-concrete composite
SLS	serviceability limit state
STIC	structural timber innovation company
TCC	timber-concrete composite
TTC	Timber-timber composite
ULS	ultimate limit state
UTS	University of Technology Sydney

Table of contents

Abstract	xix
1 Introduction.....	1
1.1 History and Background of Timber-Concrete composites.....	1
1.2 Research objectives and scope	3
1.3 Research Significance	4
1.4 Limitations.....	5
1.5 Outline of the thesis.....	5
2 Literature review.....	7
2.1 Timber-Concrete composite structures	7
2.2 Composite action of timber-concrete composite systems	8
2.3 Timber-concrete connections	11
2.3.1 Nails	15
2.3.2 SFS-Screw (VB 48-75x100)	16
2.3.3 Notch-type connection with and without dowel	19
2.4 Enhancement methods for timber-concrete composite structures.....	23
2.5 Long-term tests on timber-concrete composites.....	24
2.5.1 Summary of creep and mechano-sorptive behaviour of wood.....	24
2.5.2 Long-term experimental tests on TCC floors and beams.....	29
2.5.3 Long-term experimental tests on TCC connections only.....	38
2.6 Evaluation of the long-term behaviour of TCCs in accordance to Euro code	
5 44	
2.7 Concluding remarks.....	48
3 Timber Concrete Composite beams.....	49
3.1 Characteristics of the composite beams	49
3.2 Initial short term tests on TCC and LVL joists	52

3.2.1	Initial serviceability test on LVL joists.....	52
3.2.2	Initial Serviceability test on TCC beams	53
3.2.3	Composite efficiency of the TCC beams	55
3.3	Concluding remarks.....	61
4	Long-term testing of TCC beams	62
4.1	Test set-up	62
4.2	Environmental conditions.....	64
4.3	Moisture content.....	65
4.4	Long-term deflection of TCC beams - Discussion.....	68
4.5	Unloading of two TCC beams from long-term loads.....	73
4.6	Concluding remarks.....	74
5	Creep factor and evaluating the long-term deflection according to Euro code 5	75
5.1	Relative deflection of the TCC beams.....	75
5.2	Analytical fitted curve	77
5.3	Simplified evaluation of the long-term behaviour of TCCs in accordance to Euro code 5 using gamma method	79
5.4	Concluding remarks.....	81
6	Residual stiffness and strength tests after long-term test.....	82
6.1	Serviceability tests and loss in stiffness of TCC beams	83
6.2	Ultimate strength tests	87
6.3	Residual stiffness and strength of LVL joists	99
6.4	Concluding remarks.....	102
7	Long-term performance of timber-timber composite floor modulus.....	103
7.1	Introduction and Composite beam properties.....	103
7.2	Long-term test results and discussions	104
7.3	Concluding remarks.....	110
8	Conclusions.....	111

9 Future works	115
References	116
Appendix A	128
Appendix B	131
Appendix C	133
Appendix D	143
Appendix E	148
Appendix F	159
Appendix G	162
Appendix H	175

List of figures

Figure 1: Timber-concrete composite floor (adopted from SFS-Holz Beton-Verbundsystem)	2
Figure 2: The concept of composite action; (a) fully composite action, (b) partial composite action and (c) No composite action.....	9
Figure 3: Graphical representation of the correlation between stiffness of a shear connection and the effective bending stiffness of a composite floor (Dias 2005).....	11
Figure 4: Setting of a symmetrical push-out test	12
Figure 5: load-time curves for tests according to EN 26891(Dias 2005)	13
Figure 6: Examples of timber-concrete connections with: nails (A The concept of composite); glued reinforced concrete steel bars (A2); screws (A3); inclined screws (A4); split rings (B1); toothed plates (B2); steel tubes (B3); steel punched metal plates (B4); round indentations in timber ,with fastener preventing uplift (C1);square indentations, (C2); cup indentations and pre-stresses steel bars (C3), nailed timber planks deck and steel shear plates slotted through the deeper planks (C4), steel lattice glued to timber (D1); and steel plat glued to timber (D2) (Ceccotti 1995).....	14
Figure 7: Typical load-slip behaviour for different types of joints. (Dias, 2005).....	15
Figure 8: SFS VB screw 48-7.5x100 (Lukaszewska 2009) (all dimensions in millimetres)	17
Figure 9: Arrangement of the connectors in bending tests described by (Meierhofer 1992)	18
Figure 10: Beam with SFS screw as shear connector (Van Der Linden, 1999) (all dimension in millimetres).....	19
Figure 11: Timber-concrete connection with grooved holes and dowels (Linden, 1999) (dimensions in mm)	20
Figure 12: Shear key connection detail (Gutkowski 2004) (dimensions in mm).....	21
Figure 13: Semi prefabricated “M” section panel (Buchanan et al. 2008) (dimensions in mm)	22
Figure 14: Cross-section of the composite beam tested (Lukaszewska 2009)	23
Figure 15: Results from tensile tests made on pine (0.4x5x150 mm), loaded parallel to grain (Eriksson, Noren 1965).The upper figure shows the strain (the initial elastic strain is subtracted), measured on four samples, and the middle figure shows the free shrinkage-swelling, measured on two samples. The lower figure shows the zero-load compensated strain, i.e. the difference between the upper and the middle figure, here the medium values of the four respectively the two samples have been used (Martensson 1994).	26

Figure 16: Geometrical characteristics of the composite beam tested by Bonamini, Uzielli & Ceccotti (1990) (measured in mm)	30
Figure 17: Cross-section of the TCC tested at the EMPA laboratory, Dubendorf (kenel & Meierhofer 1998)	31
Figure 18: Timber-concrete composite section (left) and loads disposition (right) (Bou Said et al. 2004)	31
Figure 19: Comparison between calculated and measured mid-span deflections (Bou Said et al. 2004)	32
Figure 20: Longitudinal view and cross-section of the composite beam tested by Ceccotti et al. (2006) (dimensions in cm)	33
Figure 21: Mid-span vertical displacements for the timber beam and average value (Ceccotti 2006)	34
Figure 22; Longitudinal view (a) and cross-section (b) of the notched composite beam (measured in cm) (Fragiacomo et al. 2007)	35
Figure 23: Trend in time of the mid-span deflection after the placement of the concrete (b) and after the application of the dead load weights.(Fragiacomo et al. 2007)	35
Figure 24: The elevation of beam specimen 1a with SP+N* type during long-term test.(Lukaszewska 2009)	36
Figure 25: SP+N* connection type (left) and SST+S* type of connection (right) (Lukaszewska 2009)	36
Figure 26: Mid-span deflection of specimen 1a with SP+N* type during long-term test.(Lukaszewska 2009)	37
Figure 27: Mid-span deflection of specimen 2a with SST+S* type during long-term test.(Lukaszewska 2009)	37
Figure 28: <i>Long-term mid-span deflection result (Yeoh 2009)</i>	38
Figure 29: Half cross-section of the push-out specimens(left) and apparatus used in the long-term test to apply a sustained load (right) (dimensions in mm) (Fragiacomo et al. 2007)	39
Figure 30: Three types of connectors for shear tests (Mueller et al. 2008).....	41
Figure 31: Details of the three types of connection (Yeoh et al. 2011a).....	41
Figure 32: Sustained load test on connections and the cross-section of the TCC beams (Yeoh et al. 2010)	42
Figure 33: cross-section (left) and stress distribution (right) of a composite beam with flexible connection (Eurocode 5).....	44
Figure 34: Cross-section of the TCC beam (Typical) (measured in mm).....	49

Figure 35: Longitudinal elevation of the TCC beam (measured in mm) (a) B-NS, (b) B-4N, (C) B-6N, & (d) B-SFS	50
Figure 36: (1) Birds mouth with Ø16 mm coach screw, (2) Normal screw type-17 and (3) SFS screw connections	52
Figure 37: MOE test on LVL only	53
Figure 38: TCC beam under short-term test	54
Figure 39: Load vs. mid-span deflection during serviceability test for B_NS	56
Figure 40: Load vs. mid-span deflection during serviceability test for B_4N	56
Figure 41: Load vs. mid-span deflection during serviceability test for B_6N	57
Figure 42: Load vs. mid-span deflection during serviceability test for B_SFS	57
Figure 43: Location of strain gauges during (a) short-term tests on TCC beams	58
Figure 44: Strain readings along mid-span cross section for B_NS (conc. = strain reading on concrete, LVL= strain reading on the timber)	59
Figure 45: Strain readings along mid-span cross section for B_4N (conc. = strain reading on concrete, LVL= strain reading on the timber)	59
Figure 46: Strain readings along mid-span cross section for B_6N (conc. = strain reading on concrete, LVL= strain reading on the timber)	60
Figure 47: Strain readings along mid-span cross section for B_SFS (conc. = strain reading on concrete, LVL= strain reading on the timber)	60
Figure 48: Test set up (measured in mm)	62
Figure 49 Beams under quasi-permanent loads (lead bars)	63
Figure 50: Changes in relative humidity, moisture content and temperature	65
Figure 51 LVL MC Test samples	66
Figure 52 Moisture content of LVL samples versus time	67
Figure 53: Mid-span deflection versus time	68
Figure 54: Mid-span deflection and MC versus time for B-6N and B-SFS beams.	69
Figure 55 A comprehensive plot RH % and MC % and, mid-span deflection with time.	70
Figure 56: The temperature and relative humidity curve during the long-term test.	72
Figure 57: TCC beams unloaded after two years of long-term test	73
Figure 58: The relative creep of the TCC beams.	76
Figure 59: Mid-span deflection and analytical fitted curve using logarithmic function equation based on up to-date experimental results	77
Figure 60: Mid-span deflection and analytical predicted deflection for 50 years using logarithmic function equation based on up to-date experimental results	78
Figure 61: Test set up for serviceability and ultimate failure test of the TCC beams (typical) (in mm)	82

Figure 62: Location of strain gauges along the mid span of the cross section.....	83
Figure 63: Total load (2P) versus mid-span deflection at serviceability for B_NS	84
Figure 64: Total load (2P) versus mid-span deflection at serviceability for B_4N	84
Figure 65: Strain profiles along the mid-span cross section from serviceability tests for B-NS (tests done before and after the long-term test, LT= long-term test)	86
Figure 66: Strain profiles along the mid-span cross section from serviceability tests for B-4N (tests done before and after the long-term test, LT= long-term test)	86
Figure 67: Total load (2P) versus mid-span deflection at ultimate stress for B_NS.....	88
Figure 68: Total load (2P) versus mid-span deflection at ultimate stress for B_4N	88
Figure 69: Tension failure of the joist B_NS	89
Figure 70: Tension failure of the joist B_4N	89
Figure 71: Total load (2P) versus slip B_NS	90
Figure 72: Total load (2P) versus slip B_4N	90
Figure 73 Connector close to the right support after the failure test (left) and before the failure test (right) for B-4N.....	91
Figure 74 Connector close to the right support after failure for B-NS	91
Figure 75: Magnitude of the strain along the mid span cross section during ultimate test on B_NS (the numbers from 1 to 9 refer to the strain gauge numbers given in Figure 62, (- ve) strain in compression and (+ve) strain in tension	92
Figure 76: Magnitude of the strain along the mid span cross section during ultimate test on B_4N [the numbers from 1 to 9 refer to the strain gauge numbers given in Figure 62, (- ve) strain in compression and (+ve) strain in tension]	93
Figure 77: Strain profile along the mid span cross section of B-NS during ultimate test.....	94
Figure 78: Strain profile along the mid span cross section of B-4N during ultimate test.....	94
Figure 79: Set-up for bending tests of LVL joist.....	100
Figure 80: Set-up for tension test of LVL joist.....	101
Figure 81: Atypical cross section of the composite beams	103
Figure 82: Load versus deflection (Zabihi 2012, Zabihi 2014)	104
Figure 83: Long-term test set up and service loads.....	106
Figure 84: Timber composite beams in humidity chamber	106
Figure 85: Relationship between the Mid-span deflection, moisture content and relative humidity of the chamber	107
Figure 86 Relationship between deflection and length of exposure cycle (Hearmon and Paton 1964)	128
Figure 87 Deflection of loaded beech beams, Curve A, specimen maintained at R.H. 93%;Curve B, specimen, specimen loaded dry and then 'cycled'; curve, specimen	

loaded at R.H.93% and then ‘cycled’. Solid line. R.H. zero; broken line, R.H.93%.(Gibson, 1965)	129
Figure 88 Typical creep curves A, B and C, due to cycling of relative humidity between 90% and 30%, adopted from Epmeier (2007)	130
Figure 89 the lengths of the coach screw, SFS and normal screw used in the connectors ..	131
Figure 90 Location of MC samples in the fog-room.....	143
Figure 91 General layout of TCC beams in fog-room	143
Figure 92 Relationship between air humidity and moisture content (top) and deflection (bottom) with time	145
Figure 93 Relationship between deflection, moisture content and air humidity.....	146
Figure 94 Comparison of the MC measurement between small and large samples.	147
Figure 95 Relative creep of TCC beams with time.....	149
Figure 96 Logarithmic curve fitting.....	150
Figure 97 Logarithmic curve fitting.....	150
Figure 98 Magnitude of the Strain measured on tests conducted before and after long-term test for B-NS (LT= long-term test)	160
Figure 99 Magnitude of the Strain measured on tests conducted before and after long-term test for B-4N (LT= long-term test)	161
Figure 100 Connector close to the right support before (right) and after (left) failure for B-4N	171
Figure 101 Connector at L/4 from the left support before (left) and after (right) failure for B- 4N.....	171
Figure 102 Failure patterns on the LVL for B-4N	172
Figure 103 all the four connectors’ investigation after failure for B-4N (N1 left end support, N2 left at L/4, N3 right at L/4 and N4 right support).....	172
Figure 104 Connector close to the right support for B-NS.	172
Figure 105: Strain distribution along the beam cross section during short-term test (Zabihi 2012)	175
Figure 106: Relationship between the Mid-span deflection, moisture content and relative humidity of the chamber for timber only floor beams.	178

List of tables

Table 1: Properties of concrete used (Pham 2010)	51
Table 2 Type of connectors, characteristic strength and slip moduli.....	51
Table 3: The Modulus of Elasticity of the Timber (LVL) (Pham 2010).....	53
Table 4 TCC beams bending stiffness (Pham 2010).....	54
Table 5 Theoretical bending stiffness of TCC beams at serviceability.....	55
Table 6 Composite action achieved by TCC beams	58
Table 7 Instantaneous elastic mid-span deflection measured	64
Table 8 Instantaneous elastic deflection and recovery after load removal	74
Table 9 Relative creep values after three years.....	76
Table 10 Theoretical bending stiffness's using Euro code 5	80
Table 11 Comparison between the predicted theoretical Mid-span deflections according Eurocode 5 with the deflections from the experimental result	80
Table 12 Percentage loss in bending stiffness in TCC beams	85
Table 13 Summary of ultimate tests results for the TCC beams.....	87
Table 14 Comparison of the theoretical design capacity of the TCC beams using GAMMA method with the failure loads (kN) from experimental results	97
Table 15 Modulus of Elasticity of LVL after long-term test	99
Table 16 Tensile strength of LVL after long-term test	100
Table 17 Percentage loss in MOE of LVL joists	101
Table 18 Relative creep values of the composite beams.....	109
Table 19 LVL properties (Carter Holt Harvey)	131
Table 20 Shear strength of the connectors used (Khorsandnia et al 2012).....	132
Table 21 Slip moduli of the connectors used (Khorsandnia et al. 2012)	132
Table 22 Slip moduli of the connectors used (Gerber et al. 2011)	132
Table 23: Geometric properties of concrete and timber for all the TCC beams	133
Table 24: Properties of concrete used	133
Table 25 Theoretical effective serviceability bending stiffness for B-NS	134
Table 26 Theoretical effective serviceability bending stiffness for B-4N	136
Table 27 Theoretical effective serviceability bending stiffness for B-6N	138
Table 28 Theoretical effective serviceability bending stiffness for B-SFS	140
Table 29 Serviceability design load for TCC beam	144
Table 30 Weights (lead bars) on the TCC beams	144

Table 31: Transformed section properties for B_NS (typical).....	148
Table 32: Bending stiffness theoretical and experimental	149
Table 33: Concrete design creep coefficient ($t=3$ years after loading)	151
Table 34: Concrete design creep coefficient ($t=0$, instant of loading).....	151
Table 35: Concrete design shrinkage coefficient.....	152
Table 36: Long-term bending stiffness of B-6N	152
Table 37: Long-term bending stiffness of B-SFS	155
Table 38: Predicted immediate mid span deflection of the TCC beam during loading (Euro code 5).....	158
Table 39: Predicted mid span deflection of the TCC beam at the end of life (Euro code 5)	158
Table 40 Magnitude of strain along mid span cross section during serviceability test (Pham, 2010)	159
Table 41 Magnitude of strain along mid span cross section during ultimate.....	159
Table 42: ULS analysis of beam B-NS	162
Table 43: ULS analysis of the beam B-4N	166
Table 44: Results of bending test on LVL joist cut from the TCC beam (B-4N) after the ultimate test with 1260 mm clear span.....	173
Table 45: Results of bending test on LVL joist cut from the TCC beam (B-NS) after the ultimate test with 1260 mm clear span.....	173
Table 46: Results of tension test on LVL joist cut from the TCC beam (B-4N) after the ultimate test with 1000 mm clear length between the grips.....	173
Table 47: Results of tension test on LVL joist cut from the TCC beam (B-NS) after the ultimate test with 1000 mm clear length between the grips.....	174
Table 48: Design load for L6-01 and L6-03 beams according AS/NZS 1170.....	175
Table 49: The transformed section properties of the timber composite beams	176
Table 50: The analytical long-term deflection for L6-01 and L6-03 beams using GAMMA method and Euro code 5	177

Abstract

Timber concrete composites (referred to as TCC beams here onwards) consist of a concrete slab integrally connected to the timber joist by means of a shear connector. The coupling of a concrete layer on the compression side and timber on the tension side of cross-section results in efficient use of both materials. As the timber joist is mainly subjected to tension and bending while the concrete flange is mainly subjected to compression. The connection plays an important role for the composite action in determining the structural and serviceability performance of the system. Use of stiff and strong connection system contributes to a suitable bending strength and stiffness of the TCC together with other mechanical properties..

Design of timber-concrete composite systems requires verification of serviceability and ultimate limit states. With the increasing trend in long span and light-weight construction, design of these floors may be governed by serviceability limit states and deflection under long-term load is one of the serviceability criteria that need to be addressed.

The long term behaviour of timber-concrete structures depends on a number of phenomena taking place in its components. Phenomena such as creep and shrinkage effects in concrete, creep, shrinkage or swelling effects in timber and creep in connection affect long term strength, stiffness and deflection behaviour of timber-concrete composites. Creep due to variation in the moisture (mechano-sorptive creep) plays a major role in the long term behaviour of TCC floors. Few long-term experimental tests conducted so far have been reported in the literature.

The objectives and scope of this study are to conduct long-term experimental test on timber-concrete composite beams, analyse the results to determine the creep coefficient of the composite system and compare the experimental results with the analytical solutions in accordance with Eurocode 5, in which the effective modulus method is used to account the effect of creep.

To achieve the aforementioned objectives, a long-term laboratory investigation was started in August 2010 on four 5.8m span TCC beams with four different connector types. The specimens have been under sustained loads of 1.7kPa and subjected to a cyclic humidity conditions whilst the temperature remains quasi constant (22 °C). During the test, the mid-span deflection, moisture content of the timber beams and relative humidity of the air are continuously monitored. The long-term test is still continuing, two TCC beams were unloaded and tested to failure after 550 days, while the other two TCC beams are still being monitored and this report included experimental results up to the first 1400 days only. The long-term investigation on the two timber only composite floor beams commenced on March 2013 and the results are reported for the first 800 days from their commencement.